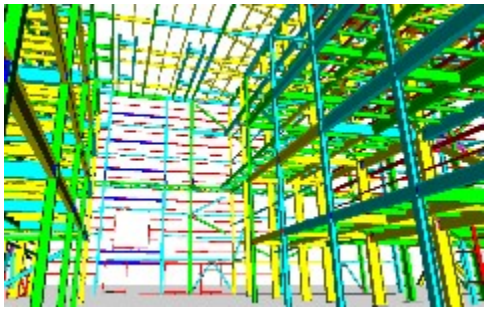
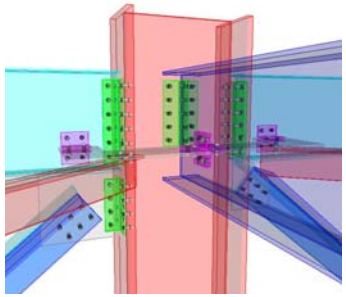
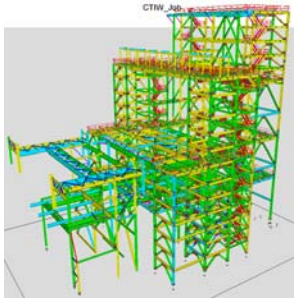
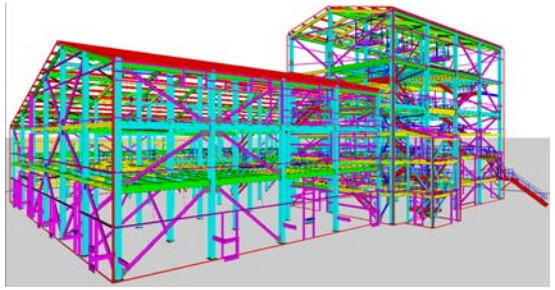
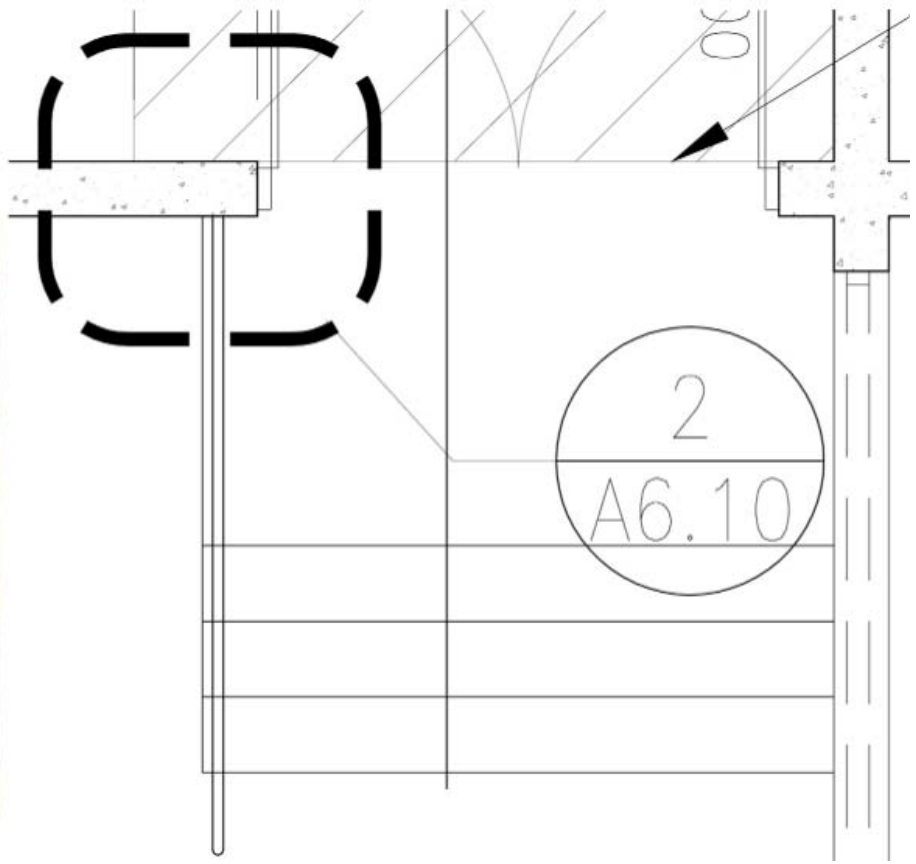
CIS/2 and IFC for Structural Steel

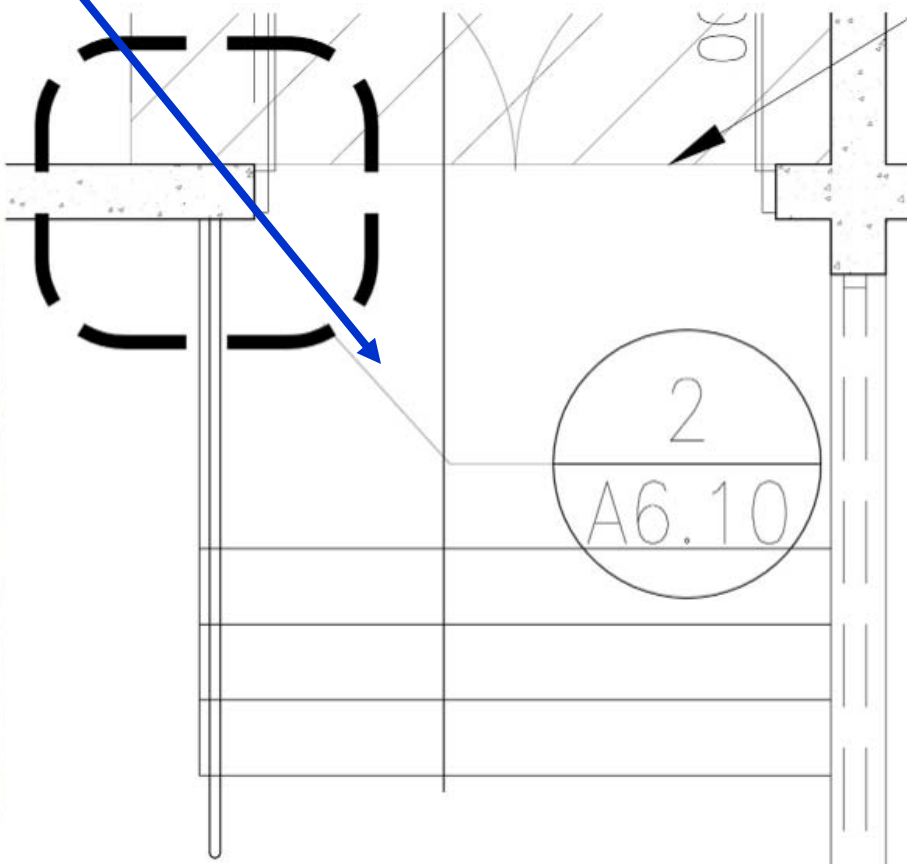
Robert Lipman
National Institute of Standards and Technology (NIST)
Computer Integrated Building Processes Group

cis2.nist.gov

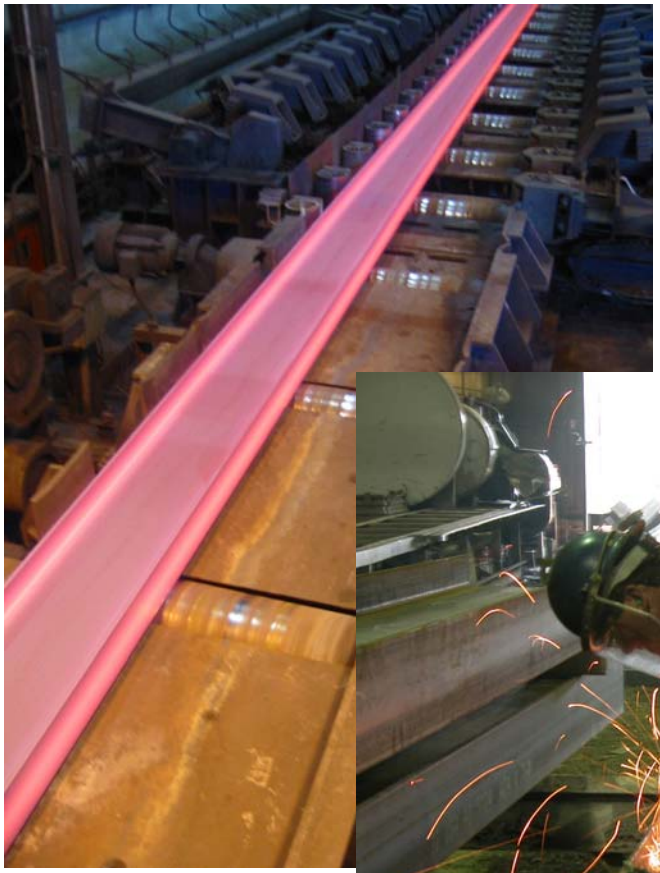
What's the point of all this data exchange?



To avoid problems like this!



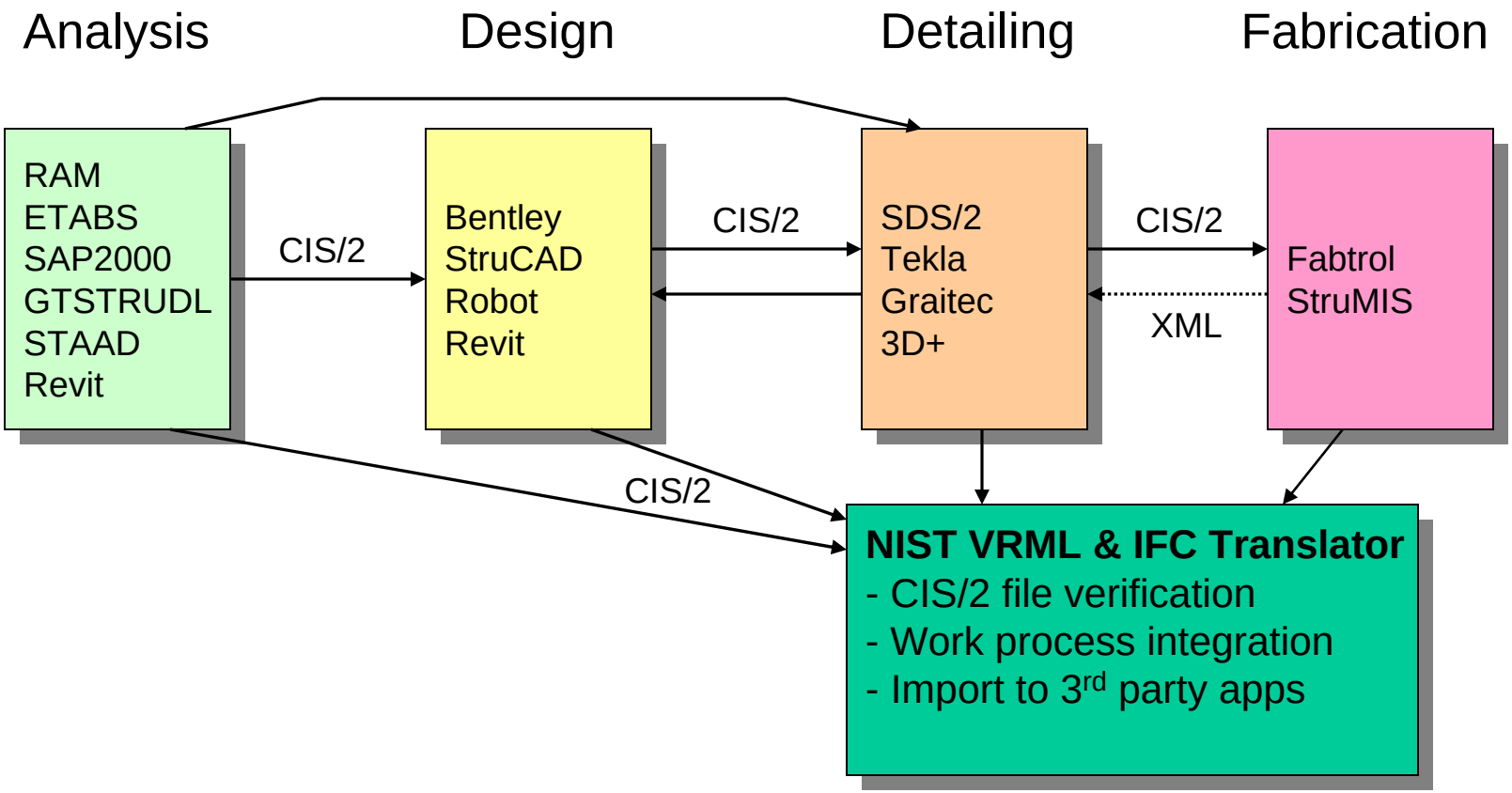
Information Representation for the Steel Supply Chain



What is CIS/2?

- CIMsteel Integration Standards
- Developed by Andrew Crowley and Alastair Watson at the Steel Construction Institute (UK)
- Adopted by the American Institute of Steel Construction (AISC) in 1998
- 15+ implementations import and/or export
- Implemented as file exchange, provides for DBMS
- Analysis, design, and detailed models
- Logical relationship between models
- Parts, assemblies, loads and reactions, materials, connections, drawing references, modification history, process information
- STEP is technical basis for CIS/2
- Schema described using Express language

Data Exchange Scenarios with the CIMsteel Integration Standards (CIS/2)



What's in a CIS/2 file (detailed model)

```
#43= LOCATED_PART(92,'92','brace',#42,#33,#20);
  #42= (COORD_SYSTEM('','Part CS',$,3)
      COORD_SYSTEM_CARTESIAN_3D(#40)COORD_SYSTEM_CHILD(#18));
    #40= AXIS2_PLACEMENT_3D('Part axes',#34,#38,#36);
      #34= CARTESIAN_POINT('Part origin',(0.,0.,0.));
      #38= DIRECTION('Part z-axis',(0.,0.,1.));
      #36= DIRECTION('Part x-axis',(1.,0.,0.));
    #18= COORD_SYSTEM_CARTESIAN_3D('','Assembly CS',$,3,#17);
      #17= AXIS2_PLACEMENT_3D('Assembly axes ',#11,#15,#13);
        #11= CARTESIAN_POINT('Assembly origin ',(720.,540.,120.));
        #15= DIRECTION('Assembly z-axis ',(-0.37139068,0.,0.92847669));
        #13= DIRECTION('Assembly x-axis ',(0.92847669,0.,0.37139068));
  #33= (PART(.UNDEFINED.,$)PART_PRISMATIC()PART_PRISMATIC_SIMPLE(#21,#26,$,$)
      STRUCTURAL_FRAME_ITEM(92,'92','brace')STRUCTURAL_FRAME_PRODUCT($)
      STRUCTURAL_FRAME_PRODUCT_WITH_MATERIAL(#27,$,$));
    #21= SECTION_PROFILE(1,'W14X158',$,$,5,.T.);
    #26= POSITIVE_LENGTH_MEASURE_WITH_UNIT
        (POSITIVE_LENGTH_MEASURE(258.48791),#3);
      #3= (CONTEXT_DEPENDENT_UNIT('INCH')LENGTH_UNIT()NAMED_UNIT(#1));
        #1= DIMENSIONAL_EXPONENTS(1.,0.,0.,0.,0.,0.,0.);
    #27= MATERIAL(1,'GRADE50',$);
  #20= LOCATED_ASSEMBLY(92,'92','brace',#18,$,#19,#10);
    #18= COORD_SYSTEM_CARTESIAN_3D('','Assembly Coordinate System',$,3,#17);
      #17= AXIS2_PLACEMENT_3D('Assembly axes ',#11,#15,#13);
        #11= CARTESIAN_POINT('Assembly origin ',(720.,540.,120.));
        #15= DIRECTION('Assembly z-axis ',(-0.37139068,0.,0.92847669));
        #13= DIRECTION('Assembly x-axis ',(0.92847669,0.,0.37139068));
    #19= ASSEMBLY_MANUFACTURING(92,'92','brace',$,$,$,$,$,$,$);
    #10= STRUCTURE(1,'cis_2','Unknown');
```

Steel part defined by a cross section, length, and material

What's in a CIS/2 file (detailed model)

```
#43= LOCATED_PART(92,'92','brace',#42,#33,#20);
  #42= (COORD_SYSTEM('','Part CS',$,3)
      COORD_SYSTEM_CARTESIAN_3D(#40)COORD_SYSTEM_CHILD(#18));
    #40= AXIS2_PLACEMENT_3D('Part axes',#34,#38,#36);
      #34= CARTESIAN_POINT('Part origin',(0.,0.,0.));
      #38= DIRECTION('Part z-axis',(0.,0.,1.));
      #36= DIRECTION('Part x-axis',(1.,0.,0.));
    #18= COORD_SYSTEM_CARTESIAN_3D('','Assembly CS',$,3,#17);
      #17= AXIS2_PLACEMENT_3D('Assembly axes ',#11,#15,#13);
        #11= CARTESIAN_POINT('Assembly origin ',(720.,540.,120.));
        #15= DIRECTION('Assembly z-axis ',(-0.37139068,0.,0.92847669));
        #13= DIRECTION('Assembly x-axis ',(0.92847669,0.,0.37139068));
  #33= (PART(.UNDEFINED.,$)PART_PRISMATIC()PART_PRISMATIC_SIMPLE(#21,#26,$,$)
      STRUCTURAL_FRAME_ITEM(92,'92','brace')STRUCTURAL_FRAME_PRODUCT($)
      STRUCTURAL_FRAME_PRODUCT_WITH_MATERIAL(#27,$,$));
    #21= SECTION_PROFILE(1,'W14X158',$,$,5,.T.);
    #26= POSITIVE_LENGTH_MEASURE_WITH_UNIT
        (POSITIVE_LENGTH_MEASURE(258.48791),#3);
      #3= (CONTEXT_DEPENDENT_UNIT('INCH')LENGTH_UNIT()NAMED_UNIT(#1));
        #1= DIMENSIONAL_EXPONENTS(1.,0.,0.,0.,0.,0.,0.);
    #27= MATERIAL(1,'GRADE50',$);
  #20= LOCATED_ASSEMBLY(92,'92','brace',#18,$,#19,#10);
    #18= COORD_SYSTEM_CARTESIAN_3D('','Assembly Coordinate System',$,3,#17);
      #17= AXIS2_PLACEMENT_3D('Assembly axes ',#11,#15,#13);
        #11= CARTESIAN_POINT('Assembly origin ',(720.,540.,120.));
        #15= DIRECTION('Assembly z-axis ',(-0.37139068,0.,0.92847669));
        #13= DIRECTION('Assembly x-axis ',(0.92847669,0.,0.37139068));
    #19= ASSEMBLY_MANUFACTURING(92,'92','brace',$,$,$,$,$,$,$);
    #10= STRUCTURE(1,'cis_2','Unknown');
```

Locating the part in an assembly

Parts refer to assemblies

Steel part defined by a cross section, length, and material

What's in a CIS/2 file (detailed model)

```
#43= LOCATED_PART(92,'92','brace',#42,#33,#20);
  #42= (COORD_SYSTEM('','Part CS',$,3)
      COORD_SYSTEM_CARTESIAN_3D(#40)COORD_SYSTEM_CHILD(#18));
    #40= AXIS2_PLACEMENT_3D('Part axes',#34,#38,#36);
      #34= CARTESIAN_POINT('Part origin',(0.,0.,0.));
      #38= DIRECTION('Part z-axis',(0.,0.,1.));
      #36= DIRECTION('Part x-axis',(1.,0.,0.));
    #18= COORD_SYSTEM_CARTESIAN_3D('','Assembly CS',$,3,#17);
      #17= AXIS2_PLACEMENT_3D('Assembly axes ',#11,#15,#13);
        #11= CARTESIAN_POINT('Assembly origin ',(720.,540.,120.));
        #15= DIRECTION('Assembly z-axis ',(-0.37139068,0.,0.92847669));
        #13= DIRECTION('Assembly x-axis ',(0.92847669,0.,0.37139068));
  #33= (PART(.UNDEFINED.,$)PART_PRISMATIC()PART_PRISMATIC_SIMPLE(#21,#26,$,$)
      STRUCTURAL_FRAME_ITEM(92,'92','brace')STRUCTURAL_FRAME_PRODUCT($)
      STRUCTURAL_FRAME_PRODUCT_WITH_MATERIAL(#27,$,$));
    #21= SECTION_PROFILE(1,'W14X158',$,$,5,.T.);
    #26= POSITIVE_LENGTH_MEASURE_WITH_UNIT
        (POSITIVE_LENGTH_MEASURE(258.48791),#3);
      #3= (CONTEXT_DEPENDENT_UNIT('INCH')LENGTH_UNIT()NAMED_UNIT(#1));
        #1= DIMENSIONAL_EXPONENTS(1.,0.,0.,0.,0.,0.,0.);
    #27= MATERIAL(1,'GRADE50',$);
  #20= LOCATED_ASSEMBLY(92,'92','brace',#18,$,#19,#10);
    #18= COORD_SYSTEM_CARTESIAN_3D('','Assembly Coordinate System',$,3,#17);
      #17= AXIS2_PLACEMENT_3D('Assembly axes ',#11,#15,#13);
        #11= CARTESIAN_POINT('Assembly origin ',(720.,540.,120.));
        #15= DIRECTION('Assembly z-axis ',(-0.37139068,0.,0.92847669));
        #13= DIRECTION('Assembly x-axis ',(0.92847669,0.,0.37139068));
    #19= ASSEMBLY_MANUFACTURING(92,'92','brace',$,$,$,$,$,$,$);
    #10= STRUCTURE(1,'cis_2','Unknown');
```

Locating the part in an assembly

Parts refer to assemblies

Steel part defined by a cross section, length, and material

Locating the assembly in an structure

Assemblies do not refer to parts

CIS/2 VRML Viewer

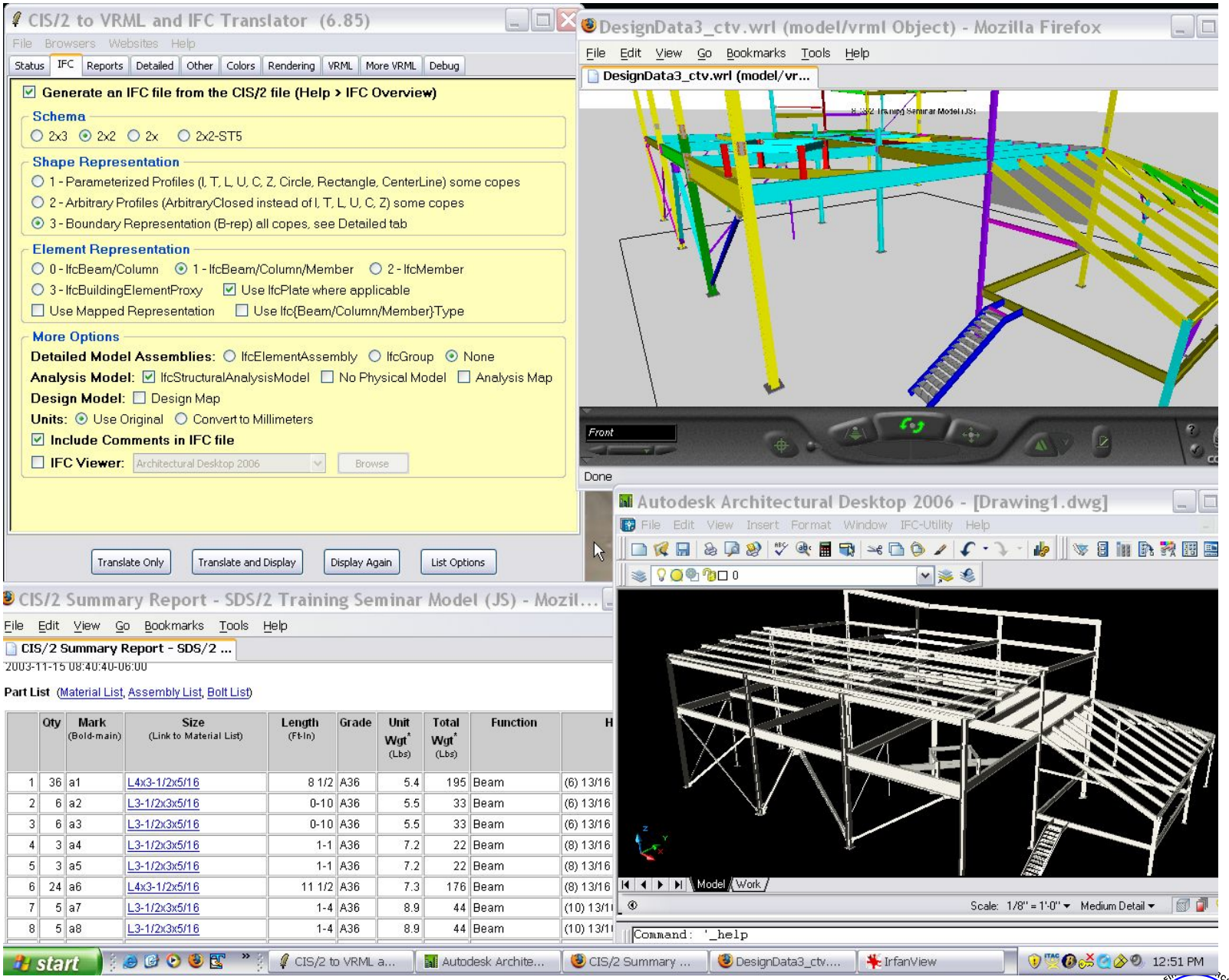
- Started development of the CIS/2 to VRML Translator - 2000
- First presented at NASCC - 2001
- Online web interface - 2001
- Windows version - 2003
- Software developers use it to verify their CIS/2 export
  - No need to exchange with other software
  - Resolve conflicts between software
  - Implement entities that are not imported by any software
- End users use it for design review, model sharing, electronic RFI, marketing, BOM, …
- Tested with over 500 CIS/2 files
- Over 1000 downloads, 100s of upgrades from older versions
- Version 7.0 released November 2006
- Integration with 3D PDF, Google Earth, Google SketchUp

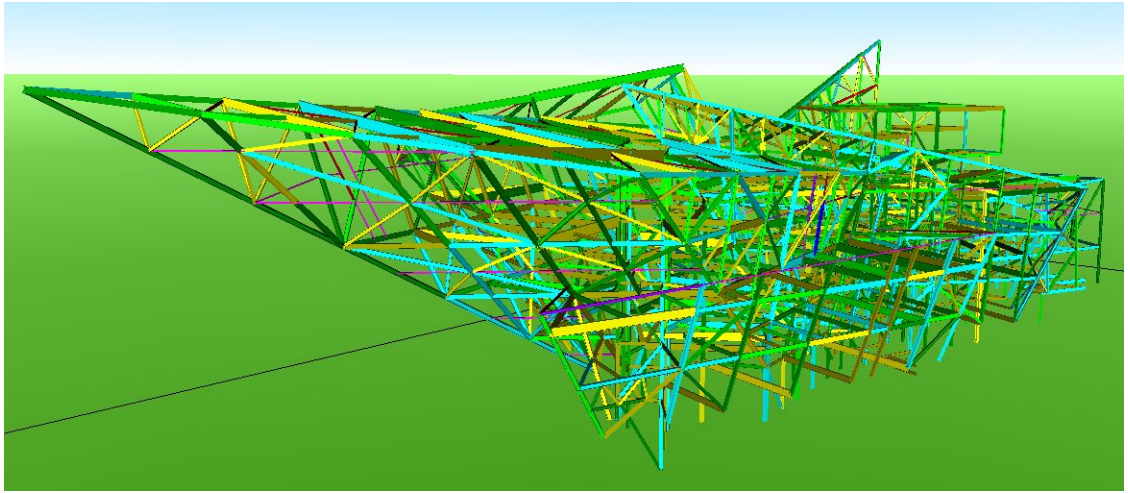
Translator user interface

VRML model

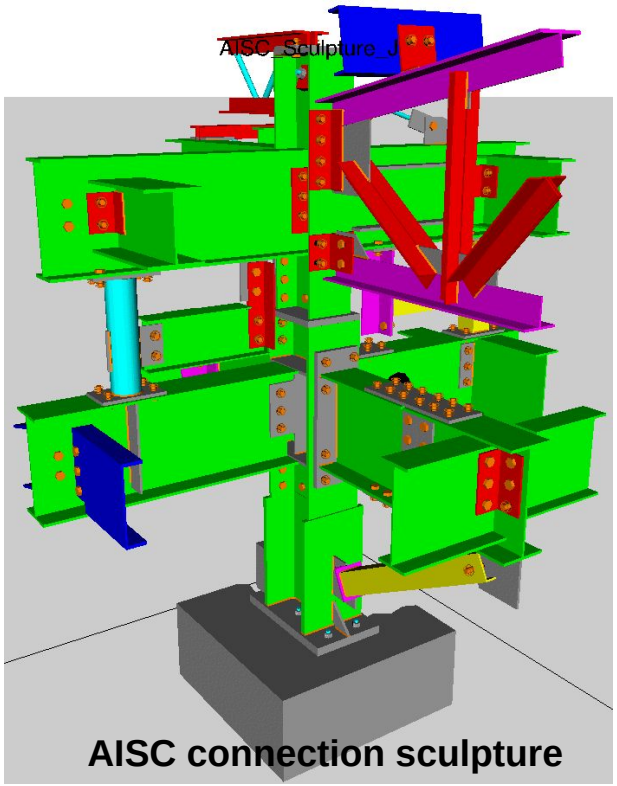
Part summary

IFC model

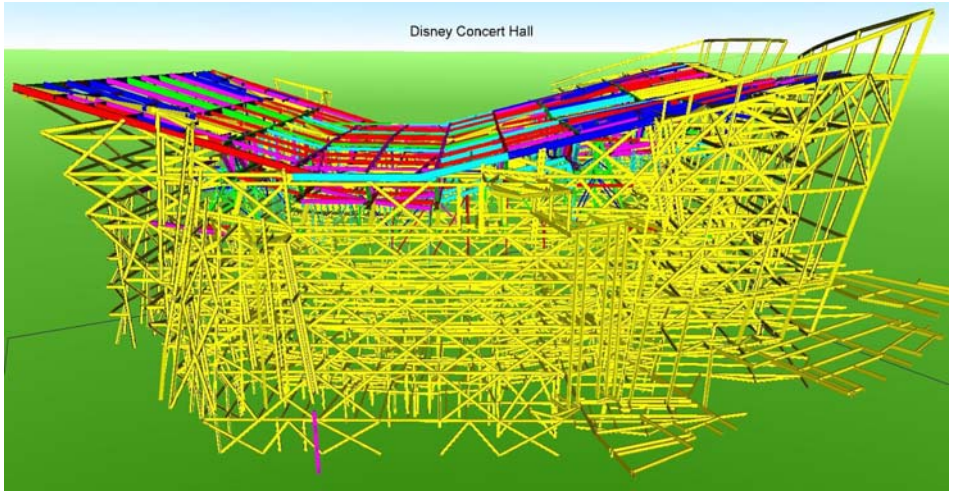




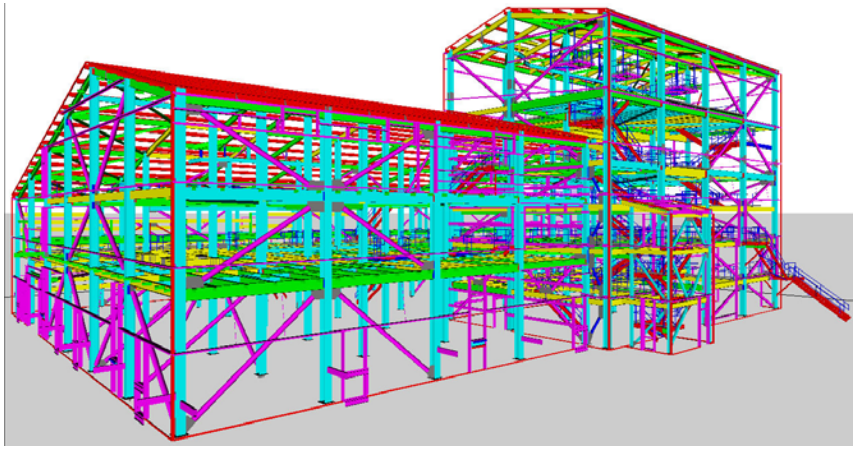
Denver Art Museum



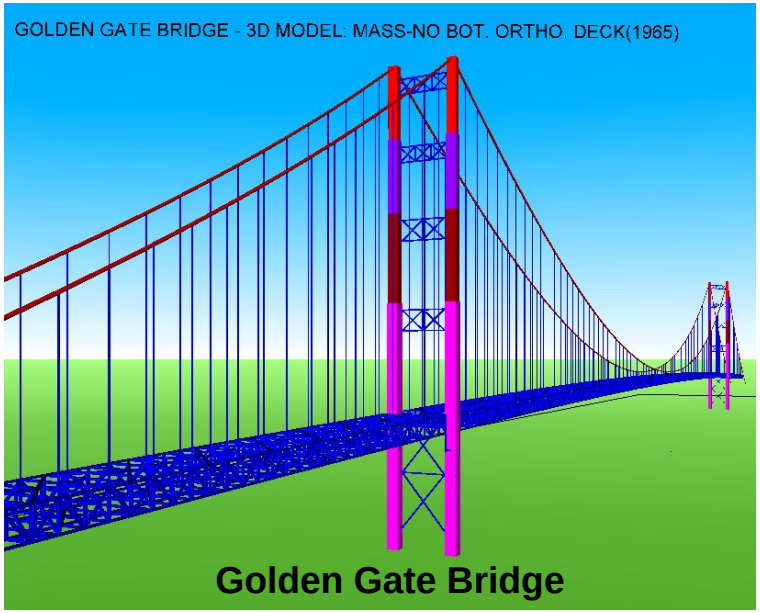
AISC connection sculpture



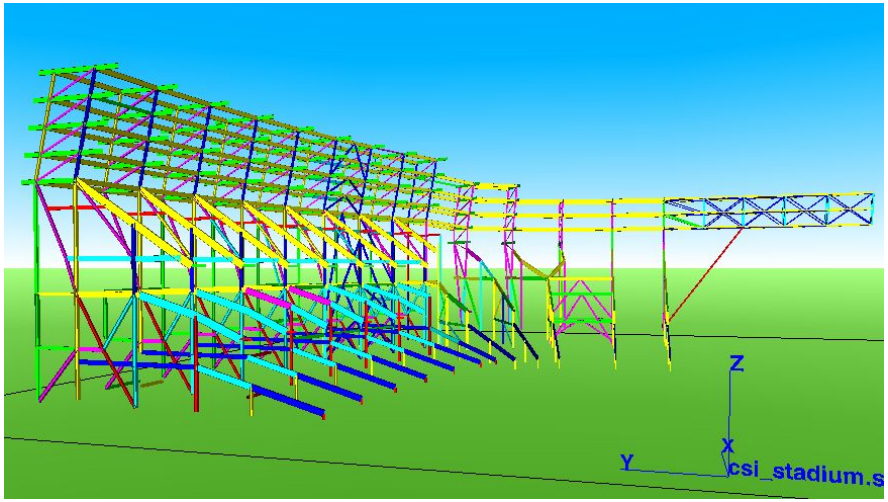
Disney Concert Hall



VRML from CIS/2 files

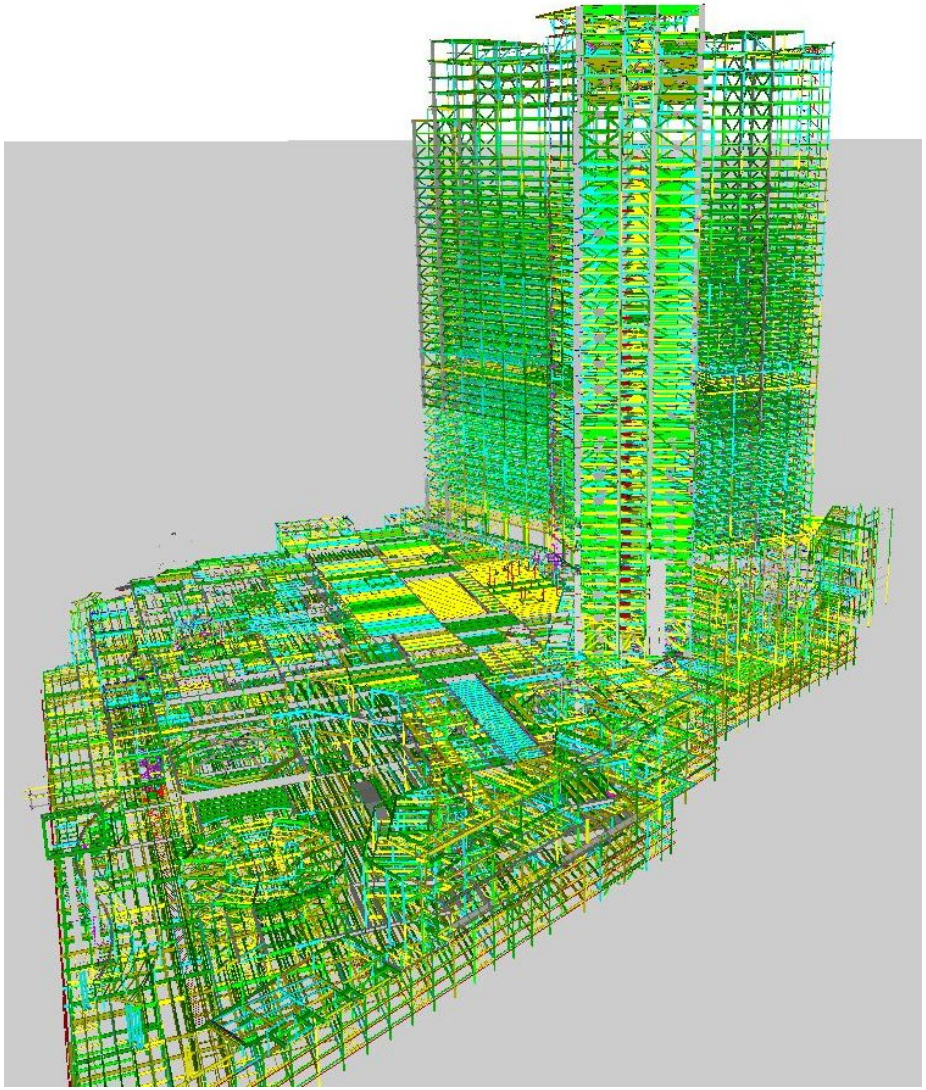


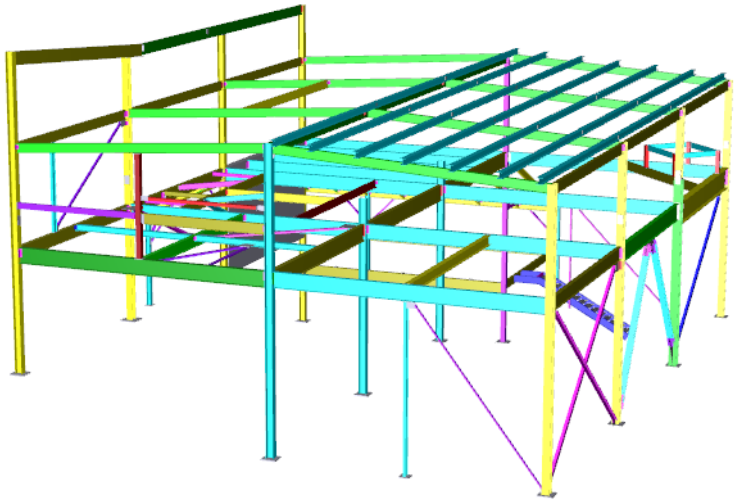
Golden Gate Bridge



Soldier Field

Las Vegas hotel – 6 CIS/2 files – 230,503 parts





What is IFC?

- Industry Foundation Classes (IFC) is the product data model developed by the IAI (International Alliance for Interoperability) to facilitate interoperability in the building industry
- Building information not geometry
- Extract information for design, analysis, facilities management, operation, quantity takeoff, energy simulation, code checking, cost estimating …
- Well defined architecture and domain extension mechanism
- Current version IFC2x3
- IFC Certification
- Implementers Support Group (ISG), Modeling Support Group (MSG)

IFC Research

- Added CIS/2 to IFC translation - 2005
- Identified deficiencies in IFC to handle structural steel, contributing to future versions of IFC
- Translator uses all IFC entities that can be used for structural steel (loads, reactions, bolts, welds, etc.)
- Provide IFC test cases for software developers of IFC importing applications
- End users moving CIS/2 models into IFC applications, for example RAM and SDS/2 to Revit and ArchiCAD to do coordination with concrete
- Contributing to future versions of the IFC schema
- Member of the IAI Structural Group, Implementers Support Group (ISG), Modeling Support Group (MSG)
- Developing Information Delivery Manual (IDM) for structural steel

What's in an IFC file

```
#147= IFCBEAM('0XNPpkfCnCVLy4HJ9X6tF_',#6005,'a2[1] L4x3-1/2x5/16','Located part',$,#119,#389,$);
  #6005= IFCOWNERHISTORY(#6003,#6004,$,.ADDED.,$,$,$,1109803792);
    #6003= IFCPERSONANDORGANIZATION(#6001,#6002,$);
      #6001= IFCPERSON($,'Barry',$,$,$,$,$,$);
      #6002= IFCORGANIZATION($,'Design Data Corporation',$,$,$);
    #6004= IFCAPPLICATION(#6002,'Unknown','SDS/2 Version 6.300 on NT','Unknown');
      #6002= IFCORGANIZATION($,'Design Data Corporation',$,$,$);
  #119= IFCLOCALPLACEMENT(#270,#241);
    #270= IFCLOCALPLACEMENT($,#239);
      #239= IFCAXIS2PLACEMENT3D(#164,#218,#217);
        #164= IFCCARTESIANPOINT((0.,0.,0.));
        #218= IFCDIRECTION((0.,0.,1.));
        #217= IFCDIRECTION((1.,0.,0.));
    #241= IFCAXIS2PLACEMENT3D(#170,#221,#220);
      #170= IFCCARTESIANPOINT((3048.,-3.30199987888336,-44.45));
      #221= IFCDIRECTION((0.,-1.,0.));
      #220= IFCDIRECTION((0.,0.,-1.));
  #389= IFCPRODUCTDEFINITIONSHAPE('a2[1]',$,(#390));
    #390= IFCSHAPEREPRESENTATION(#6011,'Body','SweptSolid',(#391));
      #6011= IFCGEOMETRICREPRESENTATIONCONTEXT('Plan','Design',3,1.0E-5,#6040,$);
        #6040= IFCAXIS2PLACEMENT3D(#6041,#6042,#6043);
          #6041= IFCCARTESIANPOINT((0.,0.,0.));
          #6042= IFCDIRECTION((1.,0.,0.));
          #6043= IFCDIRECTION((0.,1.,0.));
      #391= IFCEXTRUDEDAREASOLID(#54,#6040,#6044,139.7);
        #54= IFCLSHAPEPROFILEDEF(.AREA.,'L4X3-1/2X5/16',#304,101.6,88.9,7.9,11.1,$,$,44.45,50.8);
          #304= IFCAXIS2PLACEMENT2D(#303,#6052);
            #303= IFCCARTESIANPOINT((-44.45,50.8));
            #6052= IFCDIRECTION((1.,0.));
        #6040= IFCAXIS2PLACEMENT3D(#6041,#6042,#6043);
          #6041= IFCCARTESIANPOINT((0.,0.,0.));
          #6042= IFCDIRECTION((1.,0.,0.));
          #6043= IFCDIRECTION((0.,1.,0.));
        #6044= IFCDIRECTION((0.,0.,1.));
```

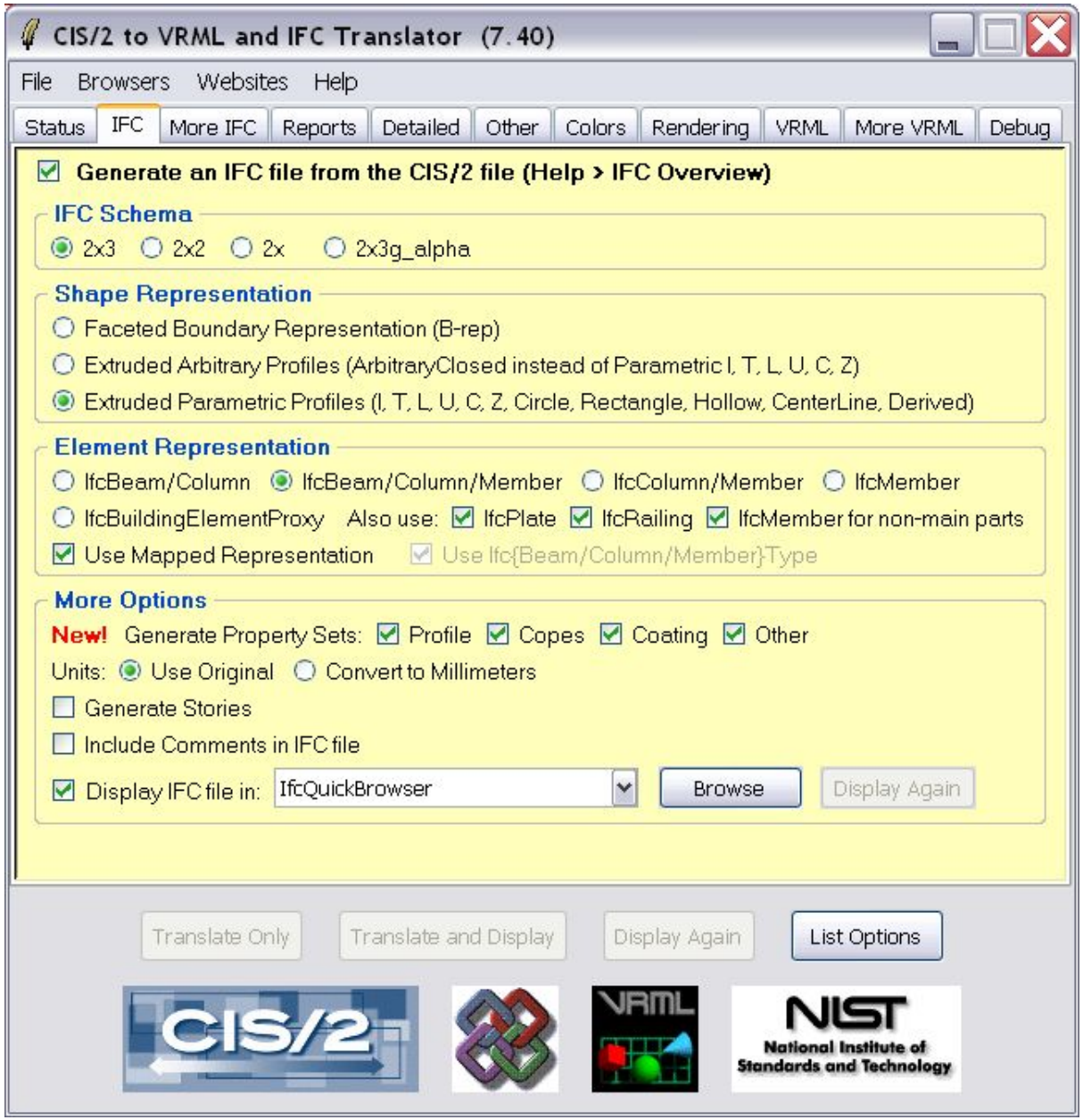
Steel part is a beam (or column, member)

Locating the part in an assembly and assembly in the structure

Other entities group parts in an assembly

Geometry of steel part defined by a cross section and length (or boundary representation)

Other entities associate materials



IFC options in the translator

< IFC schemas

< shape representations

< element representations

< property sets

< display in IFC applications

More IFC options

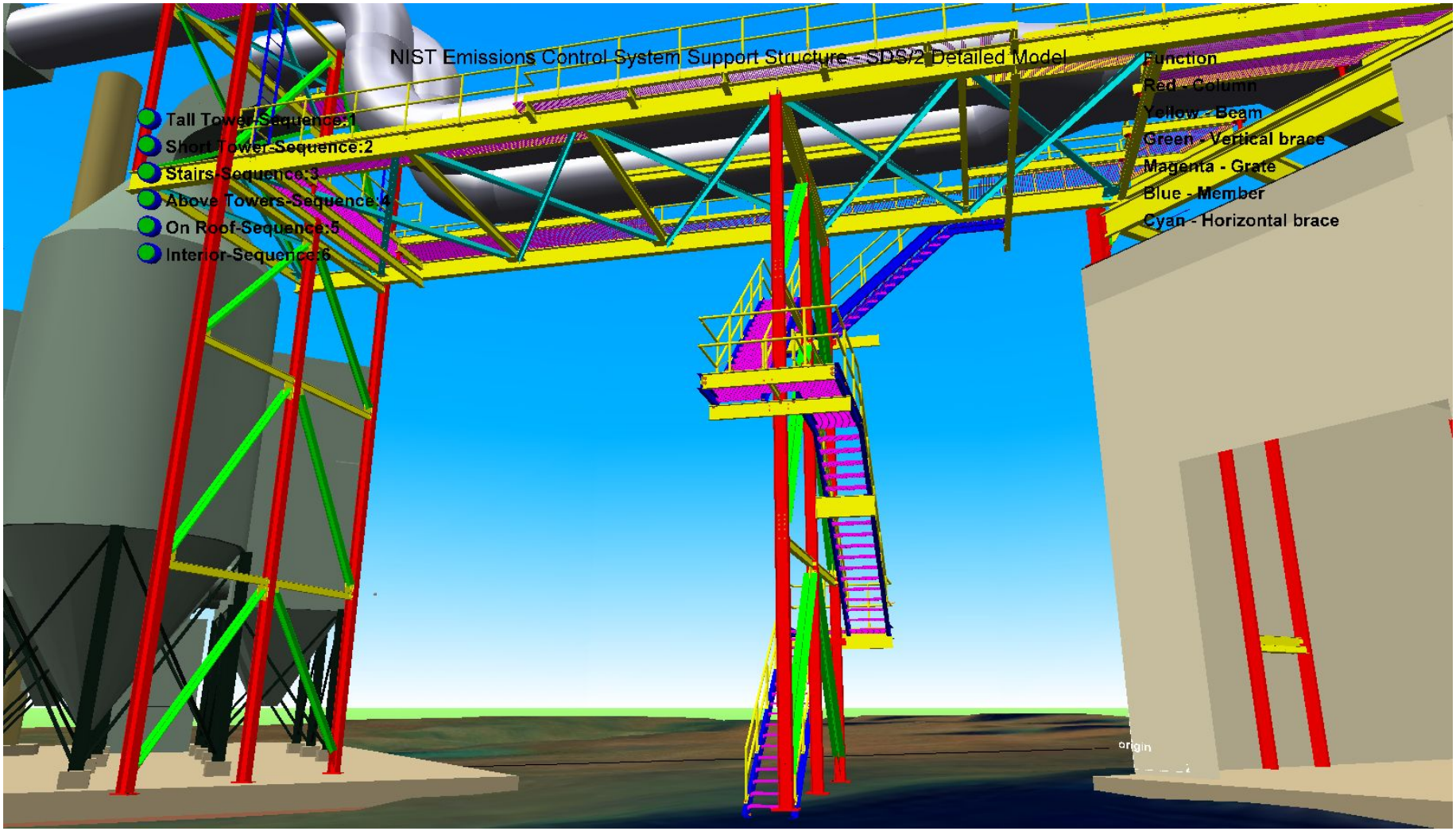
< analysis model

< assemblies

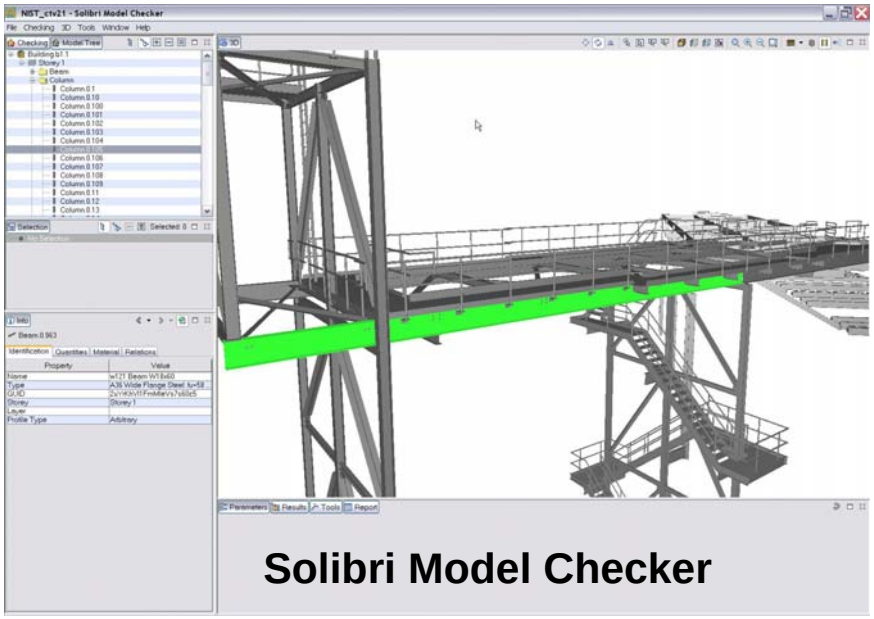
< bolts

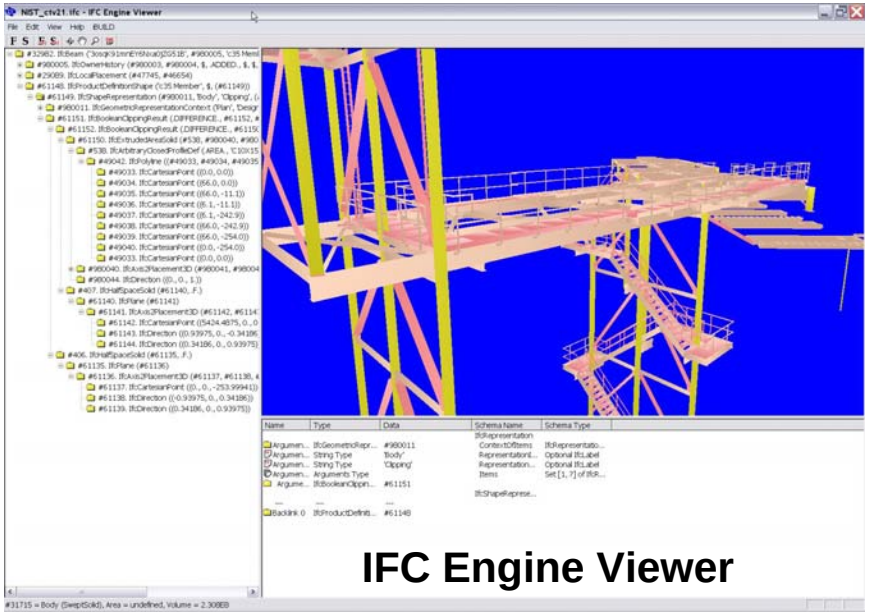
NIST Large Fire Research Facility Emissions Control System (ECS)

- **Fire tests in building (right)**
- **Steel structure carries ducts to ECS (left)**
- **Steel detailed in SDS/2 and exported to CIS/2**



VRML from CIS/2 translator (multicolored)
Building, ductwork, ECS generated by hand

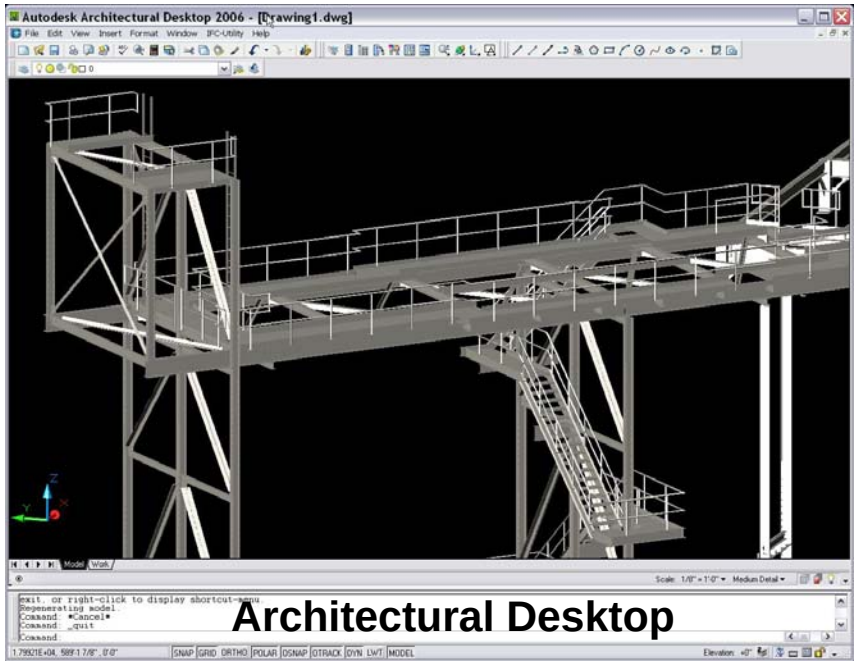


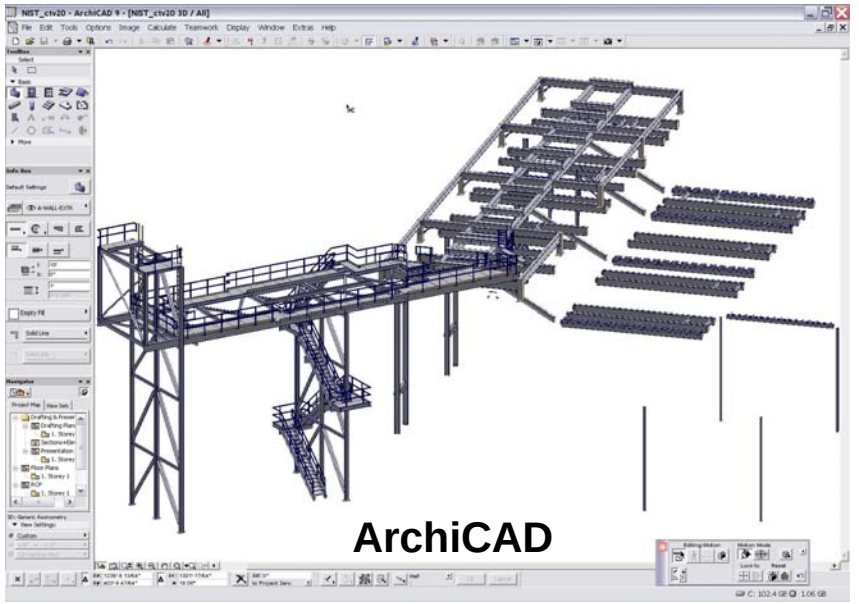


IFC file import

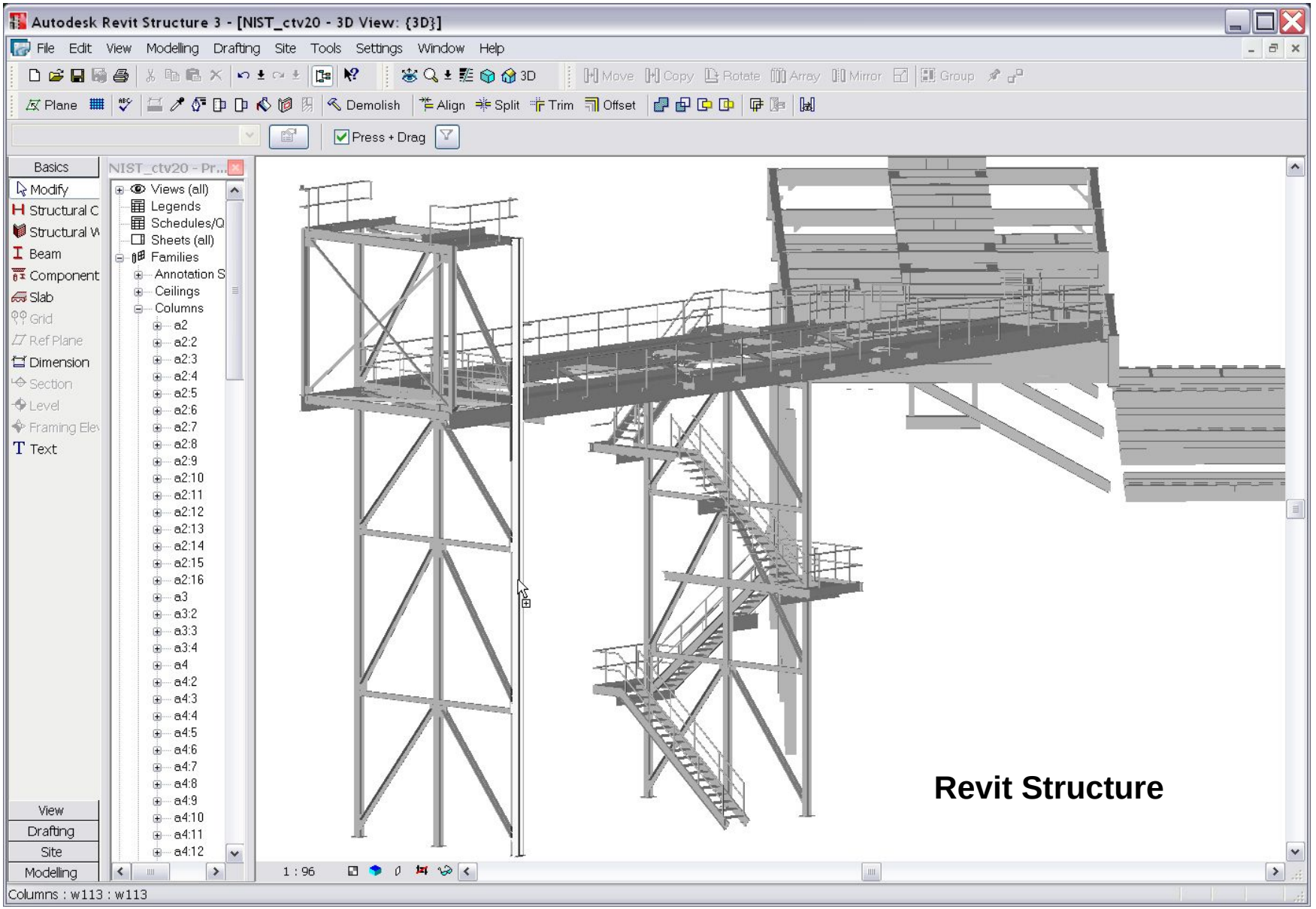
NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

BUILDING AND FIRE RESEARCH LABORATORY

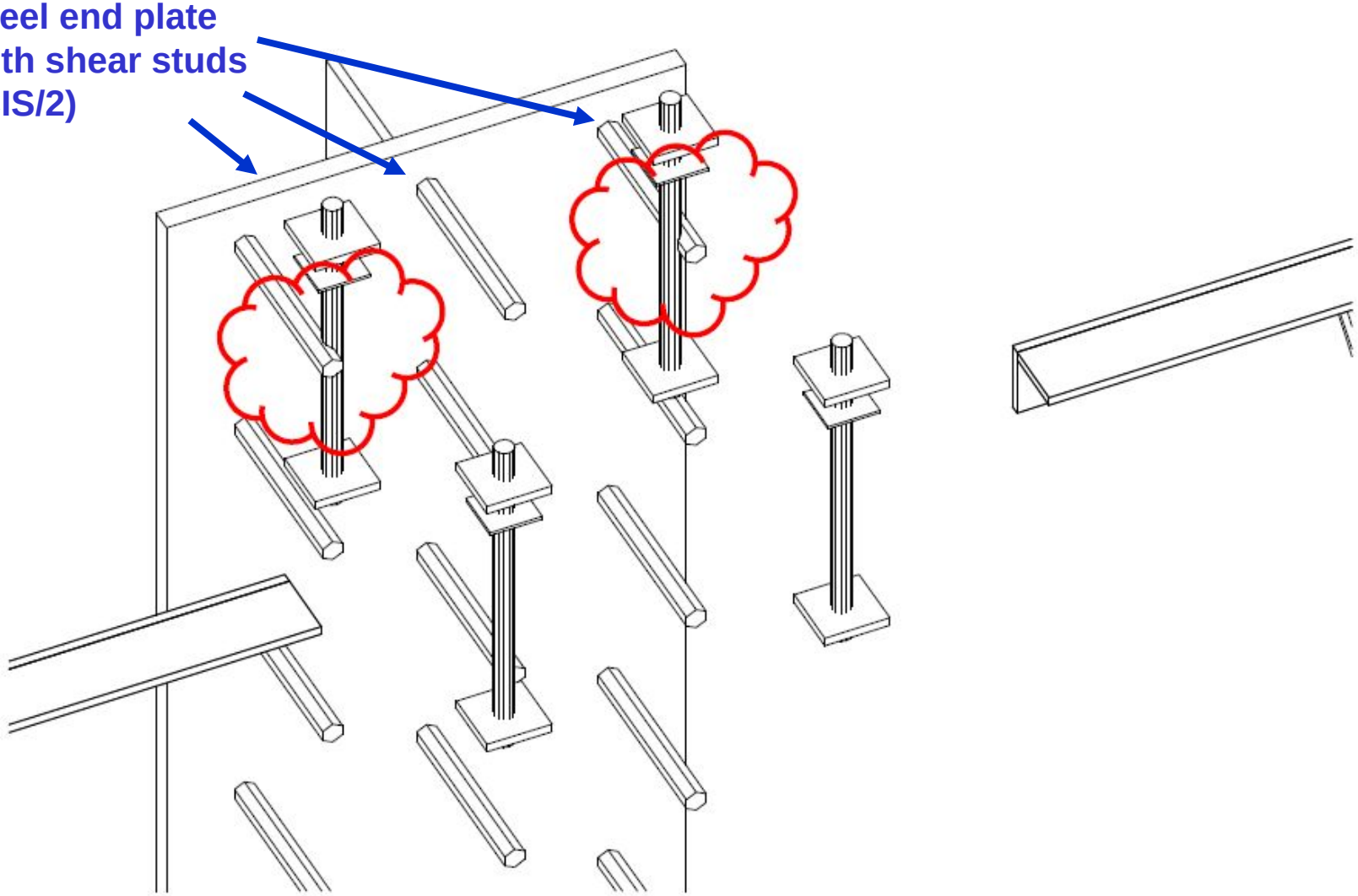




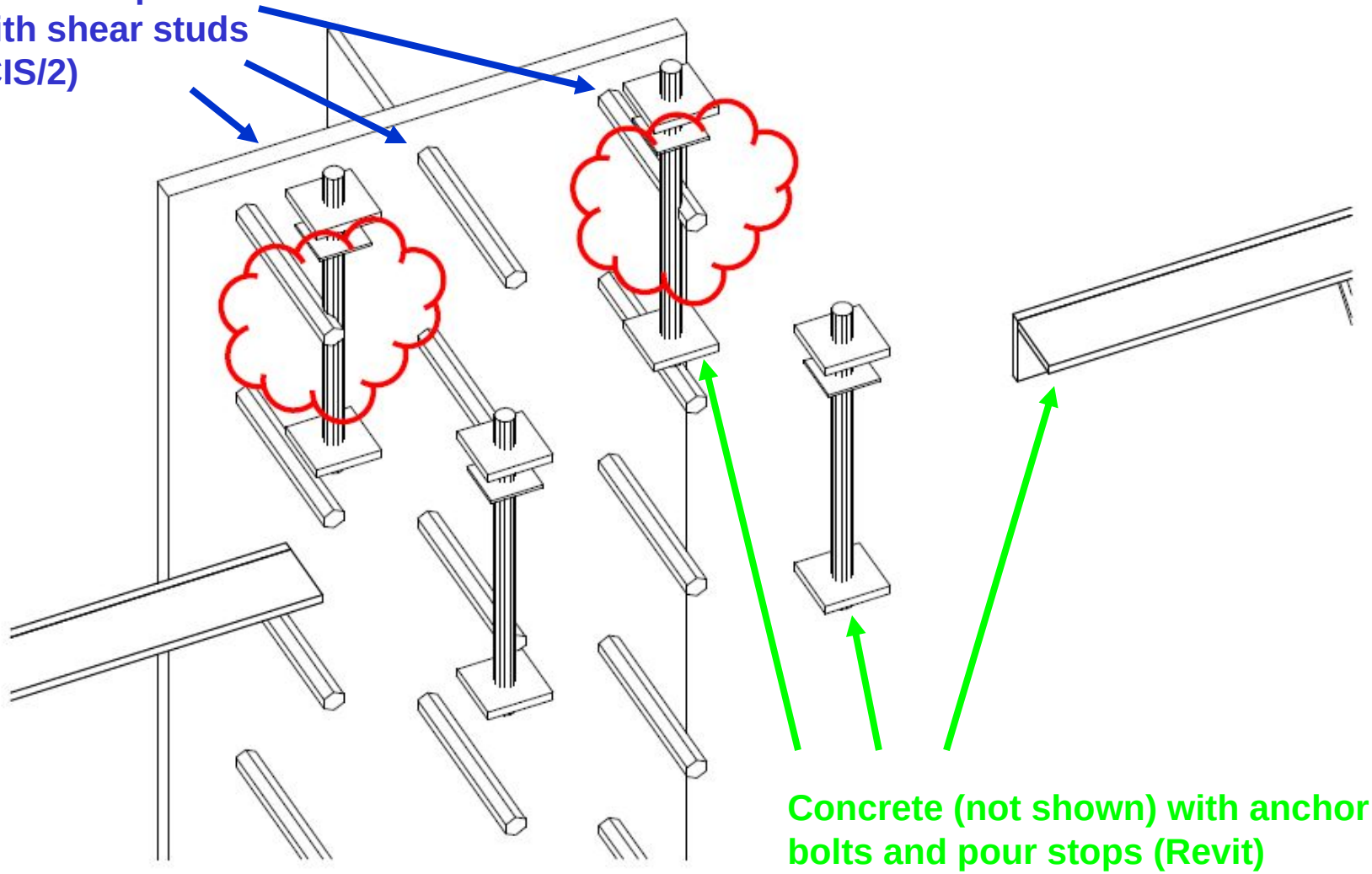
IFC file import


Autodesk Revit Structure 3 - [NIST_ctv20 - 3D View: {3D}]
File Edit View Modelling Drafting Site Tools Settings Window Help
Plane Demolish Align Split Trim Offset
Press + Drag
Basics
Modify
Structural C
Structural W
Beam
Component
Slab
Grid
Ref Plane
Dimension
Section
Level
Framing Elev
Text
NIST_ctv20 - Pr...
Views (all)
Legends
Schedules/Q
Sheets (all)
Families
Annotation S
Ceilings
Columns
a2
a2:2
a2:3
a2:4
a2:5
a2:6
a2:7
a2:8
a2:9
a2:10
a2:11
a2:12
a2:13
a2:14
a2:15
a2:16
a3
a3:2
a3:3
a3:4
a4
a4:2
a4:3
a4:4
a4:5
a4:6
a4:7
a4:8
a4:9
a4:10
a4:11
a4:12
View
Drafting
Site
Modelling
1 : 96
Columns : w113 : w113
Revit Structure

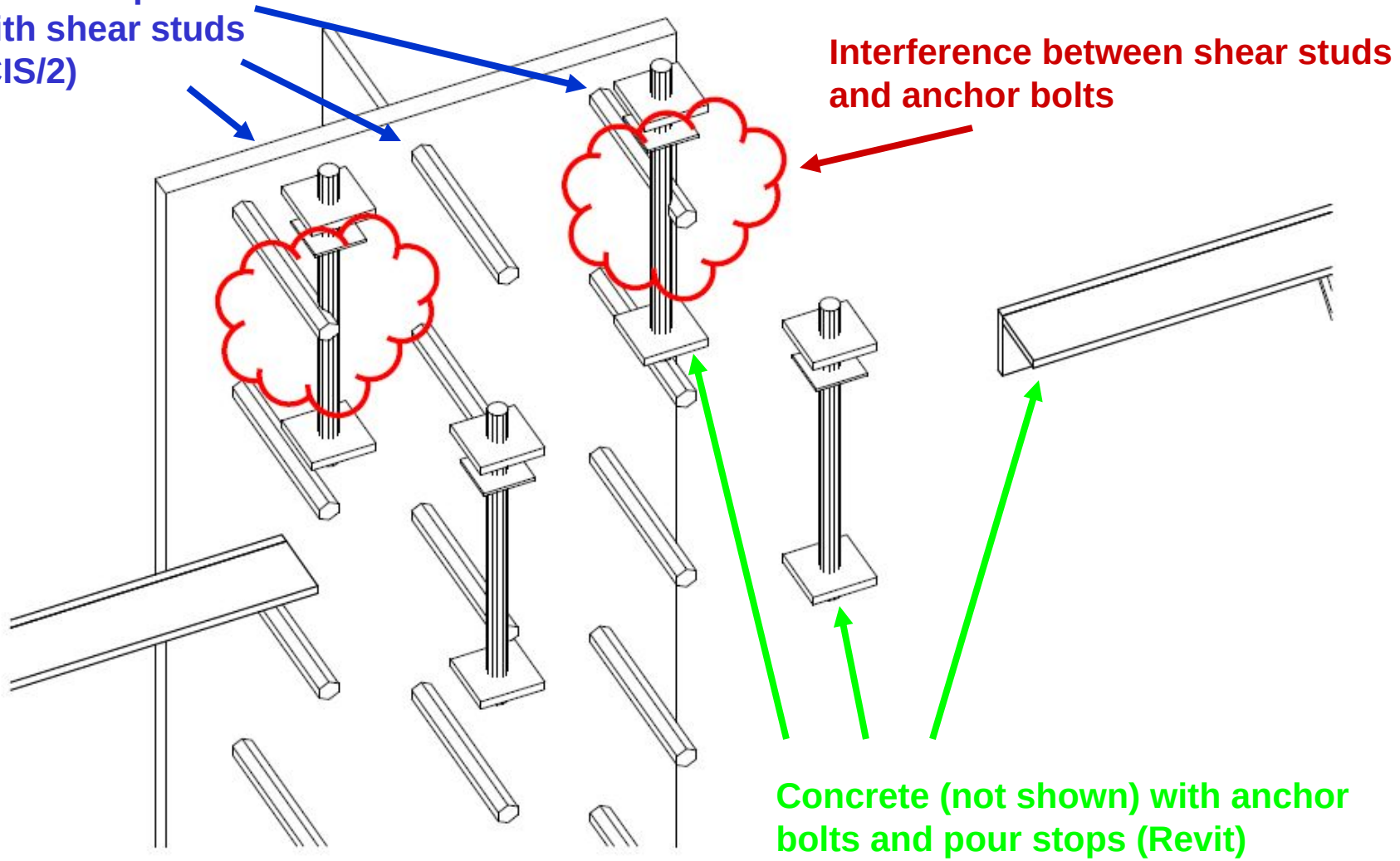
Coordination of steel (from CIS/2) and concrete in Revit



Coordination of steel (from CIS/2) and concrete in Revit

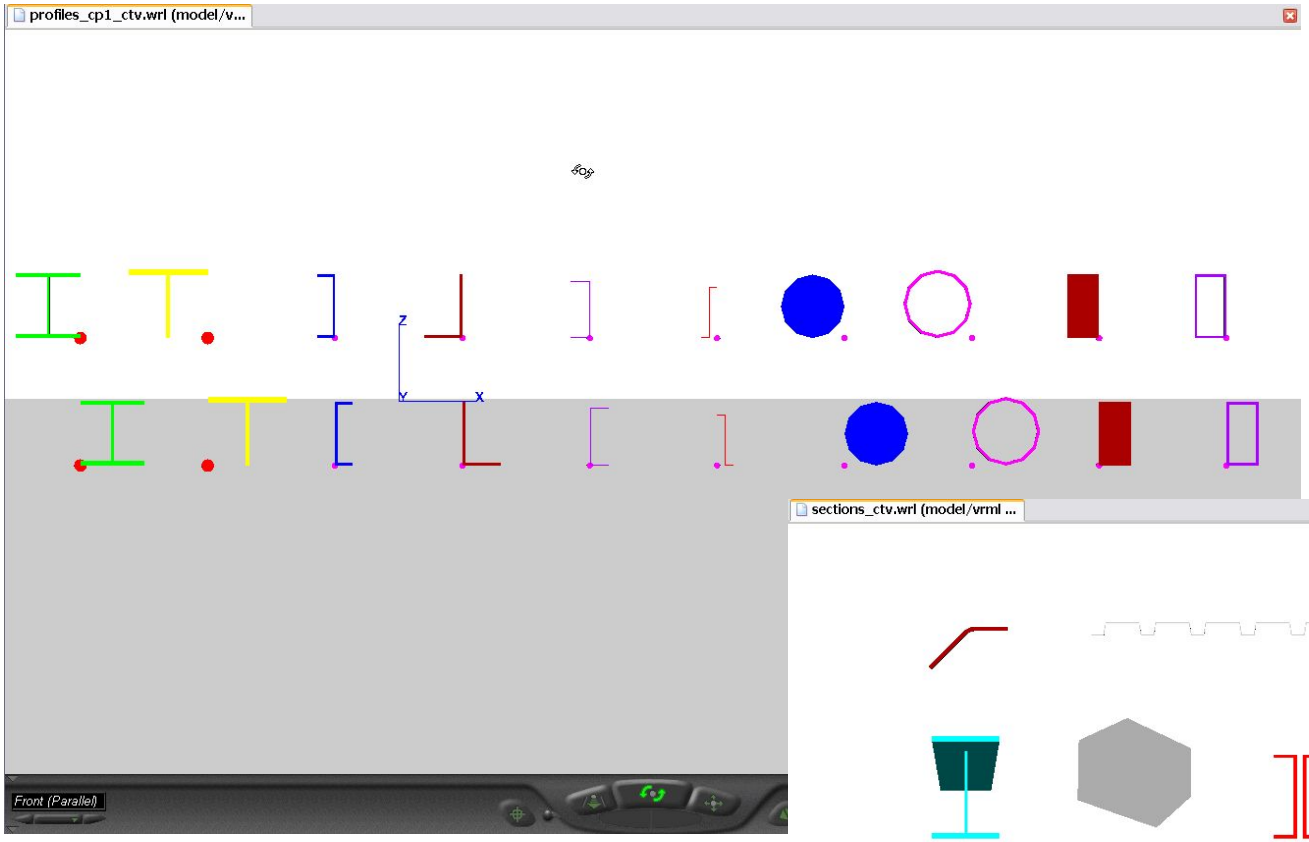


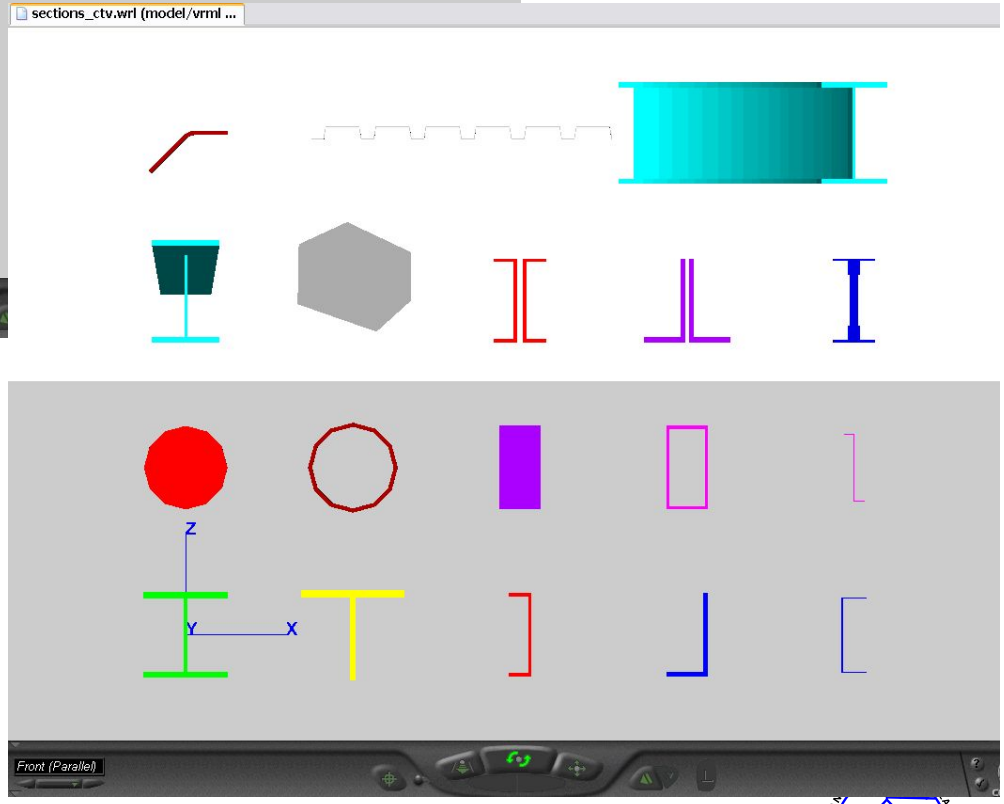
Coordination of steel (from CIS/2) and concrete in Revit



IFC Issues for Structural Steel

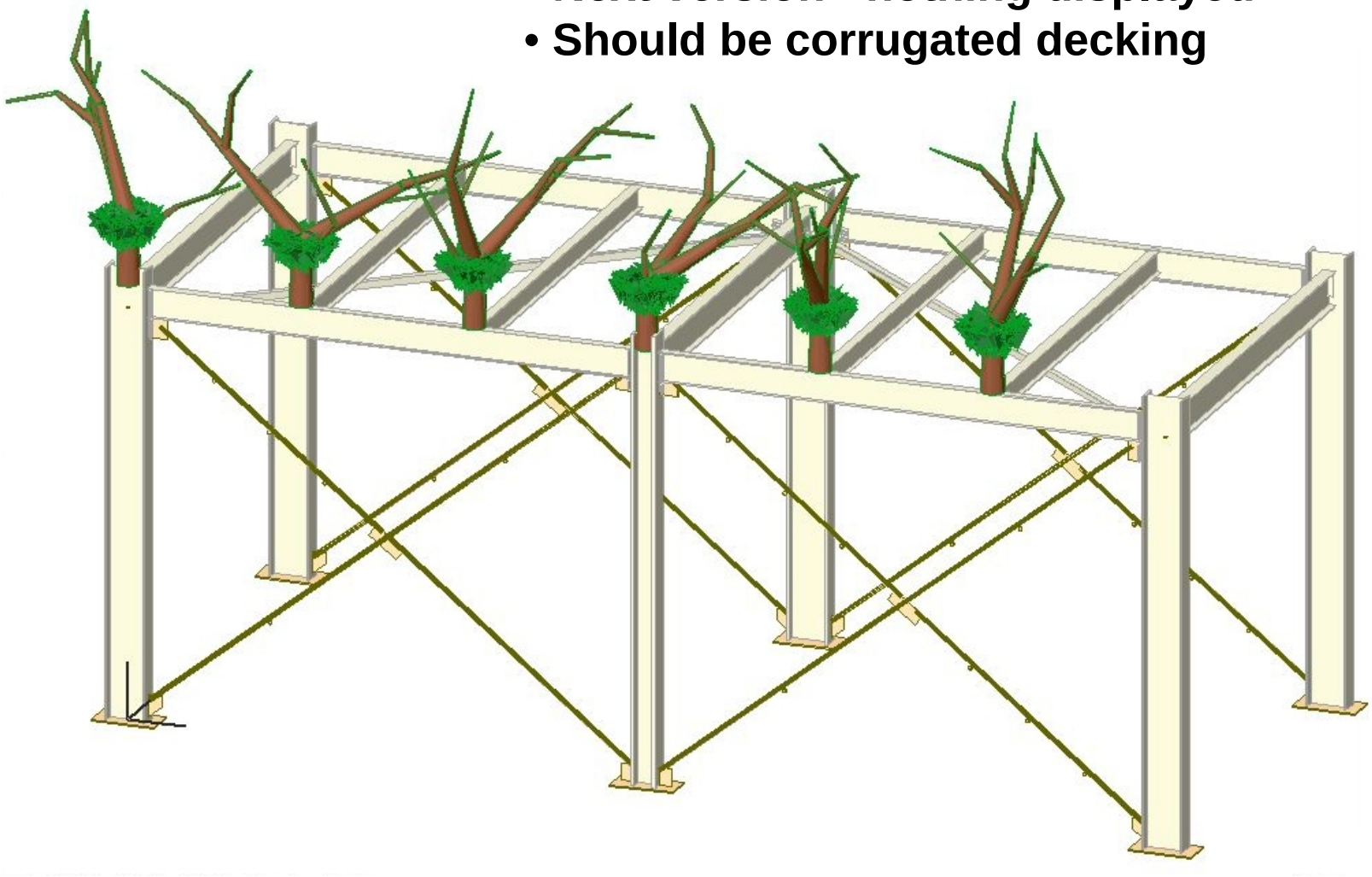
- In the previous slides, the same IFC file could not be imported into the IFC applications because of sometimes incomplete implementation of parametric profiles, one size (file) does not fit all
- Parametric profiles are essential for structural steel
- Information relevant to structural steel is lost, misplaced, or ignored when imported (piecemark, section designator, cardinal point), need agreement where that information will go
- Some things not handled well or at all or not imported: parametric profiles, bolts, welds, holes, some loads, mirrored sections, double angles, cutouts, item properties
- CIS/2 has strong notion of an assembly (main beam/column + clip angles, gusset plates)
- Explicit geometry (IFC) vs. implicit geometry (CIS/2)
- Roundtripping issues, input as parametric profile, export as B-rep, adding extra coordinate transforms
- Vendor specific property sets





Parametric profile tests

- Bad IFC file import
- Next version - trees became chairs
- Next version - nothing displayed
- Should be corrugated decking



Corrugated decking is correct

For more information:

cis2.nist.gov